arXiv:astro-ph/0309354v1 12 Sep 2003

*Future Directions in High Resolution Astronomy: The 10th Anniversary of the VLBA*
*ASP Conference Series, Vol. ***, 2003*
*J. D. Romney & M. J. Reid (eds.)*

# High Frequency Peakers: Baby Radio Sources?

Sara Tinti

*SISSA/ISAS, Via Beirut 4, Trieste, Italy, 34014*

Daniele Dallacasa

*Dipartimento di Astronomia, via Ranzani 1, Bologna, Italy, 40127*

Gianfranco De Zotti

*INAF, Osservatorio Astronomico, Vicolo dell'Osservatorio 5, Padova, Italy, 35122*

Carlo Stanghellini

*Istituto di Radioastronomia-CNR, C.P. 161, Noto, Italy, 96017*

Annalisa Celotti

*SISSA/ISAS, Via Beirut 4, Trieste, Italy, 34014*

**Abstract.** We present the results of second epoch simultaneous multi-frequency observations of 45 sources out of the 55 in the sample of High Frequency Peakers (HFP) by Dallacasa et al. (2000). Seven of the stellar sources (i.e. 16% of the total number of sources and 26% of the stellar fraction) no longer show a convex spectrum and are thus likely to be flat spectrum quasars in an outburst phase during the first epoch of observations. The rest frame peak frequency distribution of HFP quasars extends up to $\sim 45$ GHz while that of HFP galaxies is confined to $\leq 17$ GHz. Imaging at 1.465 GHz and 1.665 GHz has revealed extended emission for 31% of sources, a substantially larger fraction than found for GPS sources ($\sim 10\%$). In the case of HFP quasars, but not of HFP galaxies, extended emission is associated with strong variability, consistent with a core-jet structure.

## 1. Scientific background

The Compact Steep Spectrum (CSS) and Gigahertz Peaked Spectrum sources (GPS) are two classes of intrinsically compact objects (linear size $<$ 1 kpc) defined on the basis of their spectral properties: the overall shape is convex with the position of the turnover between 100 MHz (CSS) and few GHz (GPS) and the spectral index at high frequencies is steep (see O'Dea 1998).

The currently favoured model (the *youth scenario*) relates the small linear size of GPS/CSS sources to their age, implying that they are the progenitors of

extended radio sources. Both the spectral analysis (Murgia et al. 1999) and the dynamical studies of the separation speed of the hot spots (Owsianik & Conway 1998; Owsianik, Conway, & Polatidis 1998) provide strong evidence in favour of this hypothesis indicating age values of $10^2 - 10^3$ years.

Observational studies of the population of GPS/CSS sources have led to the discovery of a correlation between the radio turnover frequency ($\nu_{max}$) and the projected angular size ($\theta$) (O'Dea & Baum 1997; Fanti et al. 2002). This relationship is expected from synchrotron self absorption, where $\theta^2 \propto \nu_{max}^{-5/2}$ , although free-free absorption could also play a role (Bicknell, Dopita, & O'Dea 1997)). In the youth scenario this means that the youngest objects have the highest turnover frequencies.

Objects with turnover frequencies above 5 GHz, which is the limit of GPS samples, would represent smaller/*younger* sources. We call them High Frequency Peakers (HFP). One of the disadvantages of this approach is the contamination by beamed radio sources like blazars which possess radio spectra peaking above a few GHz as the result of self-absorbed synchrotron emission from the jet base.

Two epochs of simultaneous multifrequency VLA observations have been carried out to investigate the reliability of the selection criterium based on the spectral properties. Here we present the results of the second epoch of observations and we compare them with those of the first epoch (see Tinti et al., in preparation).

## 2. The Bright HFP Sample

The complete sample of candidate bright HFPs has been obtained by Dallacasa et al. (2000). Sources with $S_{4.9GHz} \geq 300$ mJy and inverted spectra (slope steeper than -0.5, S$\propto$ $\nu^{-\alpha}$) were selected in the area of the 87GB catalogue (4.9 GHz) by cross correlating it with the NVSS catalogue (1.4 GHz). The sample was then "cleaned" from variable flat spectrum sources by means of simultaneous multifrequency VLA observations at 1.365, 1.665, 4.535, 4.985, 8.085, 8.485, 14.96 and 22.46 GHz. The resulting sample consist of 55 sources with radio spectra peaking at observed frequencies ranging from a few GHz to 22 GHz.

The selection criterium is independent of optical identification and redshift. As a result both galaxies and quasars are present in the sample, which is composed of 20% galaxies, 65% stellar objects and 15% still unidentified objects. For comparison, galaxies and quasars are almost equally represented in GPS samples and most CSS sources are galaxies. This confirms that the fraction of galaxies, as opposed to quasars, decreases in samples selected at increasing turnover frequency (Fanti et al. 1990; O'Dea 1998; Stanghellini et al. 1998).

Additional observations in the same bands were carried out with the VLA for 45 sources of the original sample to study the variability in both flux density and spectral shape. Moreover this subsample has been imaged at 1.465 and 1.665 GHz by means of sensitive and longer observations in order to determine if there is any extended emission surrounding the compact source.

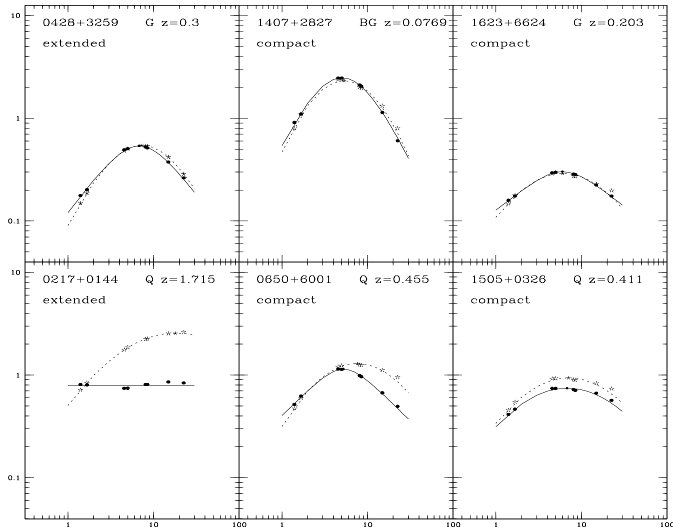


Figure 1. Radio spectra of HFP's quasars and galaxies. Stars and filled circles represent respectively the first and the second epoch of simultaneous multifrequency VLA data, while lines indicate the polynomial fit to the data-points.

## 3. Spectral analysis

In order to estimate the peak flux density and frequency of the HFP sources, we have fitted the simultaneous radio spectra at the two epochs using an hyperbolic function. A considerable fraction of sources (16%), identified as stellar objects (i.e. 26% of such objects), do not show a convex spectrum at the second epoch and are flat over the full frequency range sampled by our observations. Therefore they should be classified as flat spectrum sources, plausibly in an outburst state in the first epoch. Among the sources which preserve the convex spectral shape, HFP quasars are found to be more variable in radio flux density than galaxies (see Figure 1).

In Figure 2, the HFPs with known redshifts are plotted together with the CSS sample of Fanti et al. (1990), the GPS samples of Stanghellini et al. (1998) and Snellen et al. (1998) in the turnover frequency-linear size plane. The line is the expected correlation (in the source frame) in the case of synchrotron self absorption (Fanti et al. 2002). The distribution of HFP sources is consistent with the correlation obeyed by the other classes.

In GPS samples it has been found that quasars typically peak at higher frequencies than galaxies (Snellen et al. 1997; Stanghellini et al. 1998). Peak frequencies in the bright HFP sample are on average about a factor 5 higher than in GPS samples but still the galaxies cover a range of values lower than the quasars do (Figure 2, right panel).

## 4. Extended emission

Within our sample 14 (31%) sources show extended emission (2 galaxies, 9 quasars and 3 objects without optical identification) on scales ranging from 14 to 55 arcsec. Stanghellini et al. (1990) and Baum et al. (1990) found a

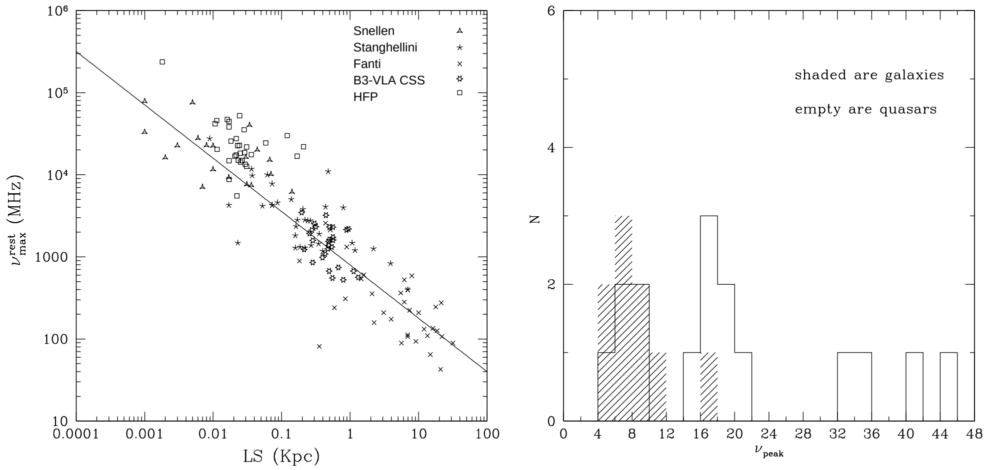


Figure 2. Rest frame turnover frequency vs. linear size for CSS/GPS samples and for the HFP sample(left). Rest frame turnover frequency distribution for galaxies and quasars at the second epoch (right).

fraction of 10% of GPS sources displaying diffuse and faint extended emission on arcsecond scales near/or around the core.

The youth scenario and the presence of radio emission on scales of tens of kpc could be reconciled by the hypothesis of recurrency proposed by Baum et al. (1990): the extended emission can be the relic of a previous large scale radio source while the peaked spectrum is due to the young central component that is propagating out admist the relic of the previous epoch of activity.

Eight out of the nine quasars with extended emission have strongly variable spectra while the only two extended galaxies in the sample both have non variable and sharply peaked spectra. The recurrent model seems to be suitable for radio galaxies, while radio quasars can be more easily explained as beamed objects whose jet is pointing towards the observer and whose radio emission is dominated by a single compact component. Milli-arcsecond images at different frequencies can distinguish between a core-jet structure, typically associated to blazars, and the CSO-like structure expected for young or recurrent objects.

## 5. Conclusion

The fraction of quasars compared to galaxies is substantially higher in our sample than in samples of GPS sources.

Although in the literature GPS sources are frequently referred to as non variable (but see Stanghellini 2003), many of our sources and especially quasars are found to be variable.

A substantial fraction (31%) of our HFP sources show extended emission which, in the case of quasars, is associated in most cases with strong variability. On the other hand, the two galaxies with extended emission are non variable. This adds to the body of evidence that GPS galaxies and quasars likely represent a different phenomenon and that for quasars the beamed emission from compact components id dominant.

Spectral selection relying on high turnover frequencies is an easier method for selecting candidate young sources than the morphological selection. However the contamination of spectrally selected samples by Doppler boosted objects increases with turnover frequency.

We plan to complete the analysis and the identification of the sample using high resolution observations to study the mas morphology. VLBA observations, at two different frequencies in the optically thin part of the spectrum, have been already carried out and the analysis of the data is in progress.

## References

Baum, S.A., O'Dea, C.P., de Bruyn, A.G., & Murphy, D.W. 1990, A&A, 232, 19

Bicknell, G., Dopita, M. A., & O'Dea, C. P. 1997, ApJ, 485, 112

Dallacasa, D., Stanghellini, C., Cetonza, M., & Fanti, R. 2000, A&A, 363, 887

Fanti R., Fanti C., Schilizzi R.T., Spencer, R.E., Nan Rendong, Parma, P., van Breugel, W.J.M., & Venturi, T. 1990,A&A, 231, 333

Fanti, C., & Fanti, R. 2002,in Issues in Unification of Active Galactic Nuclei, ASP Conference Series 258, ed R. Maiolino, A. Marconi & N. Nagar (San Francisco: ASP), 261

Murgia, M., Fanti, C., Fanti, R., Gregorini, L., Klein U., Mack, K-H., & Vigotti, M. 1999, A&A, 345,769

O'Dea, C.P., & Baum, S. A. 1997, AJ, 113, 148

O'Dea, C.P. 1998, PASP, 110, 493

Owsianik, I., & Conway, J.E. 1998, A&A, 337, 69

Owsianik, I., Conway, J.E., & Polatidis, A.G. 1998, A&A, 336, L37

Snellen I. A. G. 1997, PhD thesis, Leiden Observatory

Snellen, I.A.G., Schilizzi, R.T., de Bruyn A.G., et al., 1998, *A&AS*, **131**, 435

Stanghellini, C., Baum, S.A., O'Dea, C.P., & Morris, G. B. 1990, A&A, 233, 379

Stanghellini, C., O'Dea, C.P., Dallacasa, D., Baum, S.A., Fanti, R., Fanti, C. 1998, A&AS, 131, 303

Stanghellini C. 2003, PASA, 20, 118S